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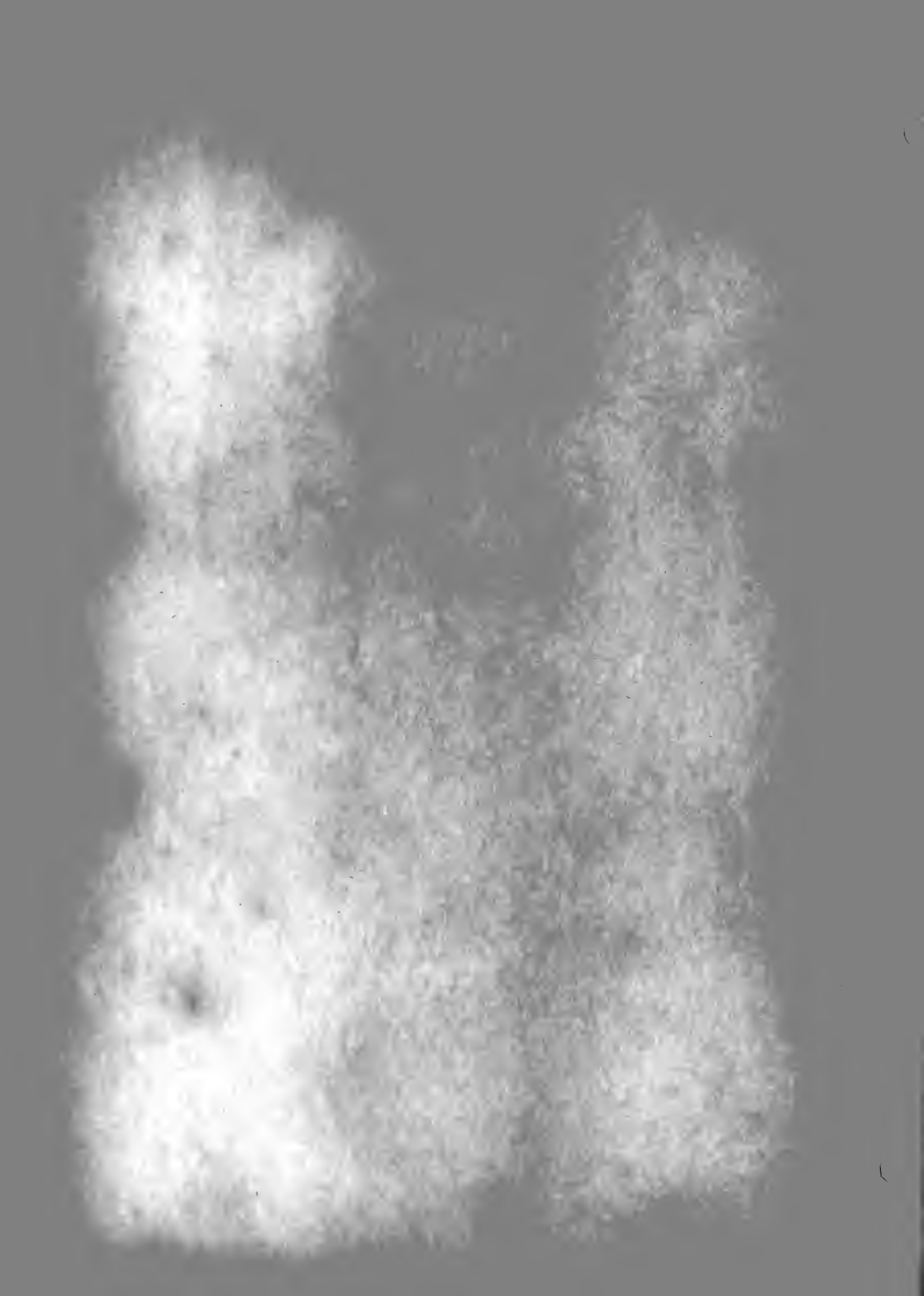

OPERATIONS ANALYSIS IN THE UNITED STATES NAVY

by

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PREFACE

This study of the role of operations analysis in the Navy was made at the United States Naval Postgraduate School during the latter half of the academic year, 1953-1954. The purpose of this study is to acquaint naval officers further with the use of operations analysis as an aid in solving complex operational problems.

The definition of operations analysis introduced here, in terms of optimization of achievement of purpose, was first suggested by Professor C.C. Torrance. In the writer's opinion, this definition describes operations analysis more clearly than any of the many others contained in the current literature.

The author is grateful to Professor W.R. Church and to Professor C.C. Torrance of the United States Naval Postgraduate School for their guidance in the preparation of this study.

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ABSTRACT

A study is presented here of the role of operations analysis in the United States Navy. A definition of operations analysis is given, and the general implications of this definition are discussed. The methodology for solving problems arising in complex operations, the relation between the analyst and the executive, the problems of decision inherent in every operations analysis study, and the scope of operations analysis are examined. An example of a past application of operations analysis is described in order to discern the conditions necessary for successful accomplishment of operations analysis studies.

The increasing need for operations analysis in the Navy is emphasized in light of the impact of technological advances on the military sciences. This need may, in part, be met through the use of officers formally trained in operations analysis. But certain problems arise when members of the military service are employed as analysts, and these problems are quite different from those attendant upon the use of civilians. These problems are discussed in order to determine how the Navy can best meet its need for operations analysis.

In past military applications, operations analysis has been largely confined to problems arising in combat operations. In view of the widespread applications of the methods of operations analysis in other fields, recommendations are made as to future possible applications of operations analysis in the Navy.

CHAPTER I

INTRODUCTION

The concept of using teams of scientists to work at operational levels in military commands was of British origin, when a small trouble-shooting party of scientists was attached to the early-warning radar chain in 1940. Operations analysis in the United States Navy had its formal beginning in April 1942 when a group of civilian scientists was assigned to the Navy to carry out research in anti-submarine operation. These groups of scientists achieved remarkable successes in resolving wartime operational problems. Similar groups of scientists were then added to the other military services. In the course of their work, many members of these groups became convinced that the techniques used in operations analysis were not limited to military problems; chiefly as a result of their effort, widespread applications of these techniques are being made in industry today.

Because of the recent origin of operations analysis, there are many different formulations of its definition and scope. While a considerable amount of literature dealing with past applications of operations analysis exists, and an Operations Research Society of America has been formed to encourage and publicize current efforts in the field, much work remains to be done to acquaint all potential users with its true meaning and possible uses. It is quite obvious that this task is of such magnitude as to preclude the possibility of its being accomplished in a study of this nature. It is felt, however, that a study of operations analysis in the Navy may be made here.

The author, along with 14 other naval officers, is currently completing a two year curriculum in operations analysis at the United States Naval Postgraduate School. The requirements for entrance into this curriculum are a minimum of six years operational experience and some demonstrated degree of proficiency in mathematics. Consideration of this background makes it evident that there are many officers in the Navy better able to describe the operational features of the problems discussed here; on the other hand, there are many scientists better able to describe the scientific nature of operations analysis. Our particular background does, however, enable us to discuss many naval problems from both the scientific and operational point of view.

Since, to the author's knowledge, nothing has been written on the problems attendant upon the use of naval officers in the role of operations analysts, investigation of these particular problems would appear to be of interest.

CHAPTER II

WHAT IS OPERATIONS ANALYSIS

1. Definition of Operations Analysis

Operations analysis is a rapidly expanding discipline. Partial or interim definitions of it range from quality control and cost analysis to personnel management. There seems as yet to be no generally accepted definition of the subject. In the most general sense, operations analysis is the scientific analysis of a going operation. The following definition of operations analysis (operations research) resulted from the experiences of the Operations Research Group gained during the war years (7,Page 1):

> Operations research is a scientific method of providing executive departments with a quantitative basis for decisions regarding operations under their control.

Since this study is concerned with operations analysis in the Navy, and the Operations Research Group was the formal organization created to conduct research into operations for the Navy, this definition may be logically chosen as the starting point for our discussion. In order to develop an acceptable interpretation of it, let us consider the terms " a scientific method", "executive", and "decisions".

2. A Scientific Method

One may well be disturbed by the vagueness of the phrase, " a scientific method", and the military commander may well question how an operations analyst can solve a problem in a manner in any way different from that followed by members of his staff. Now in many respects the two solutions may not differ at all, for in the sense that the staff member observes data, collects facts, and bases his solution upon them, he is employing scientific methods. The differences between the methods of the analyst and the staff member may be merely in the objectivity of their

observations, the elaborateness of the trials and experiments conducted, or in the complexity of the respective calculations. The use of scientific methods is not restricted to the scientist; indeed, most people employ these methods daily to a certain degree. However, we note from the above definition that the analyst restricts himself to the use of a scientific method. This restriction does not hold for the staff member, who, if he does not use a scientific method exclusively, may base his solution at least in part upon guidance from higher authority or upon speculation (intuition, native judgment, or other "faculty").

Guidance from higher authority consists of directives, and these directives are laws to which the staff member must necessarily adhere, in the same manner that the scientist must follow the laws of science. Where directives and scientific laws have their basis in fact, and are applicable to a given situation, both sets of laws form perfectly acceptable bases for the solution of problems. While directives frequently change, this in itself is not proof that they were originally wrong, but rather emphasizes their dependence upon situations which can change in such a manner as to render them inapplicable. Incidentally, scientific hypotheses and doctrines also change as mankind's state of knowledge increases, and scientists must take great pains to use only those scientific principles that are applicable to a given situation.

The method of consulting authority has limited application. In general, rules and policies can not be adequately formulated to cover every complex situation. In many cases, guidance from higher authority may be non-existent, or directives may be conflicting. The choice of a method for solving a problem must then be between a scientific method and speculation.

To avoid giving an impression of uncertainty in a decision reached by speculation, people customarily resort to such phrases as, "In my judgment", or "It has been my experience". When a person expresses such a decision it is difficult to know how much of it is pure speculation and how much is actually the result of applying scientific methods. It is this curious blend of speculation and scientific reasoning which guides most of us in solving complex problems, and one thus speaks of an experienced man, or of one who has an intuitive feel for an operation. Operations analysis does not regard the views of experienced men lightly; on the contrary, by using formal scientific methods, it is often led to the same conclusion as the operator who learned by doing. It does seek, however, to apply scientific methods as rigorously as possible in all cases, and thereby increase the reliability and certainty of an operational decision.

Although written before the formal advent of operations analysis, K. Pearson (9, Page 12) described clearly what is meant by the aims and method of science:

> The classification of facts and the formation of absolute judgments upon the basis of this classification - judgments independent of the idiosyncrasies of the individual mind-essentially sum up the aim and method of modern science. The scientific man has above all things to strive at self-elimination in his judgments, to provide an argument which is as true for each individual mind as for his own. The classification of facts, the recognition of their sequence and relative significance is the function of science, and the habit of forming a judgment upon these facts unbiased by personal feeling is characteristic of what may be termed the scientific frame of mind.

Operations analysts have accepted Pearson's definition of the scientific frame of mind, but doubt that there is any such thing as THE scientific method, believing rather as J.B. Conant (2, Page 45) has stated:

> There is no such thing as THE scientific method. If there was, surely an examination of the history of physics, chemistry, and biology would reveal it. For as I have already pointed out, few would deny that it is the progress in physics, chemistry, and experimental biology which gives everyone confidence in the procedures of the scientist. Yet a careful examination of these subjects fails to reveal any one method by means of which the masters in these fields broke new ground.

It is for this reason that analysts choose to describe their work as the application of "a scientific method", preferring to let the nature of the problem dictate the particular method to be employed. It is also the reason why operations analysis is customarily regarded as a team effort, with the members drawn from many different fields of science.

In summary, we have seen that although there are various ways in which problems can be solved, the operations analyst restricts himself to only one, the application of a scientific method. To the question of whether or not this is sufficiently novel in itself to be called operations analysis, the answer is no, for like the famous character in Moliere's comedy who had been speaking prose all his life without knowing it, so man has applied scientific methods since the day he first began to draw inferences from observations, crude though the methods might be.

3. The Analyst and the Executive

One notes from the definition in Section 1, that the separate existence of the analyst and the executive is implied. Writing on this subject, P.M. Morse and G.E. Kimball (7, Pages 2 and 138) state:

> This separation of the duties and activities of the research worker and the executive is important; the experience of the past ten years has only emphasized this importance. Experience has shown, for instance, that a person with operations research training, when placed in an executive position, loses a great deal of his usefulness as an operations research worker (though he may become an excellent executive). The requirement that the executive

> reach a decision concerning an operation is to some extent antagonistic to the requirement that he look at it scientifically and impersonally as would be required in operations research. The proper use of an operations research group by an executive department implies a sort of symbiosis, requiring on the part of each, trust in the other's activities and respect of the others prerogatives.....It is a fundamental property of operations research that operations research groups must have broad knowledge, but should have very little power and responsibility. Operations research workers must be able to think about the military situation impersonally and impartially, and this can be done best if they are relieved of the responsibility of issuing orders. Their conclusions must take the form of advice to some high ranking officer, for him to make the orders (if he sees fit).

The writer does not believe that these views are necessarily correct. One may well wonder what yardstick of measurement was used to arrive at the conclusion that a person with operations research training loses a great deal of his effectiveness as an operations research worker when placed in an executive position. It is of course true that the pressure of other duties may decrease the amount of time that the executive may devote to pure operations research. But the perspective attained by operations analysis experience may sometimes find its greatest payoff in the guidance it provides an executive in appraising the conclusions and recommendations of analysts.

As far as the attitude of mutual trust between the analyst and the executive is concerned, it seems to the writer that a good healthy attitude of check-and-counter check is more in keeping with the spirit of operations analysis. Analysts, in describing their working routine, note that one of the greatest benefits of using a team is that which accrues from the very rigorous criticism of a study by all the members of the team. It is, of course, the very aim of a scientific method, as Pearson stated, "to provide an argument which is as true for each individual mind as his (the analysts) own". To advocate that the executive

should base his decision upon a study which he is incapable of doing himself (and presumably understanding) is to advocate that he should use guidance from authority to solve his problems. It is difficult to believe that any executive is going to base his decision upon a complex mathematical formula with which he is unfamiliar, and the analyst is fully aware of this. As a result, the formal operations analysis study is prepared so that inferences can be clearly drawn by anyone reading the report. In this sense the executive uses a scientific method, and it is only a matter of organization and qualifications that determines who actually does the calculating.

It is true that the executive cannot view impersonally an operation about which he has to make a decision, for in any thought process, bias and knowledge are intimately connected. Certainly no one contends that the scientist, whose methods the analyst seeks to emulate, is an unbiased person and thus incapable of doing scientific research on a subject. The history of science reveals many instances where only the dogged determination and persistent belief in his views carried the scientist through long years of criticism, until he was able to prove in an acceptable manner that he was correct. When the scientist's theories prove inconsistent with scientific methods they are discarded, and consistent theories are adopted. The analyst and the executive, being human, must work in a similar manner, and there seems to be no reason why the executive should have any more difficulty in overcoming bias than the analyst or anyone else. A good executive begins his decision by calling for the facts, and thus follows a scientific approach.

As to the idea that the responsibility of decision is actually antagonistic to impersonal and scientific appraisal, it would seem that such an antagonism can occur only when it is considered that there are

aspects of an operational problem outside the purview of the analyst, such as political considerations. The proper solution in any such situation is, of course, not to sequester the analyst, but to broaden his purview.

Since in military applications of operations analysis the analyst has usually been a civilian, and thus separate from the executive, one can question if the use of a separate organization, whose members employ scientific methods to assist the executive in his problems, is sufficient to be called operations analysis. Again we are led to an answer in the negative, for while one may have difficulty in establishing the date at which the advisory body changed from soothsayers to men of science, this concept is not new. In our lifetime we have become accustomed to executives employing management engineers, efficiency experts, consulting engineers, and a host of similar scientific advisors.

It is only when we direct our thoughts to problems of decision regarding an operation that we discover that operations analysis is indeed a new discipline.

4. Problems of Decision

From a reading of the definition in Section 1, the reader is lead to the idea that somehow the analyst is given a problem, applies a scientific method to solve it, and then hands the solution to the executive who may or may not follow it in determining his final course of action. The writer does not mean to be unnecessarily critical of this definition, for it is intended to be a very broad one, but in its generality it fails to describe the essentially new feature of operations analysis: the very nature of the problem of operations analysis.

There are two problems of decision in every operations analysis study. The first problem is to decide upon the purpose of the operation. In many cases this is a most difficult decision. Often, the optimal conduct of an operation is comparatively simple to determine, once the decision regarding purpose of the operation has been made. It is the idea of employing scientific methods to decide upon the purpose of an operation, and then of optimizing the achievement of this purpose that is truly new and of such importance as to be called a new discipline. World War II marked the first time that large organizations (in this case the military) formally adopted the practice of having both trained scientists and executives view the entire complex operation, determine its purpose, and devise means to optimize the achievement of this purpose. It was this procedure in solving complex operational problems that gave unexpectedly great returns for very little expenditure of effort.

In some cases it is fairly simple to decide upon the purpose of an operation, but in any case this is the starting point in operations analysis. A case discussed in the current literature demonstrates very clearly how meaningless it is to talk about operations analysis until the decision regarding purpose of the operation has been made. In this particular example, an analyst on field duty observed that a certain group of men spent a long time waiting in a mess line. Noting that two tubs were used for rinsing and two tubs for washing the trays, the analyst, by a few simple calculations, was able to show that the waiting line could be eliminated if instead three tubs were used for washing, and one for rinsing. This was cited as a case where operations analysis,

using solely the equipment at hand, was able to perform a small miracle. A humorous and caustic comment appeared in The Operations Research Society Journal for November 1953, containing a ficticious interview with the hardened mess sergeant who was purported to have remembered the case. He recalled that the "old man" had said to follow the advice, but that they quickly went back to the old routine when the analyst left because the bacteria count got so high in the rinse tubs that half the men were in sick bay with dysentry, and in any case,"everyone"knew that it was good for the men to stand in line to develop their leg muscles for long marches.

The case is a humorous and trivial one, but its extension to more serious cases is obvious. While both the analyst and the mess sergeant may have employed scientific methods, they arrived at opposite conclusions, for they each solved a different problem. The thing that is lacking to make this a case for operations analysis is a decision on the purpose of the entire operation. Once it is made, it is obvious that reaching an agreeable solution could be a simple matter.

The actual formulation of a problem must be a joint effort between the analyst and the executive. As members of the Operations Research Group have pointed out, it is not to be expected that nontechnical officers, immersed in the pressures of command responsibilities, should be able to formulate effectively the problems for the analyst to work on, rather, the analyst must get close enough to the action to help in its formulation. It is in this respect that operations analysis differs markedly from the more familiar "completed staff work" upon which the executive is often forced to rely.

Once the purpose of an operation has been decided upon, a solution must be obtained. The particular method of solution will depend upon the nature of the problem. Often the collection and analysis of existind data is sufficient. Where this is lacking, controlled experiments or trials may be used. In more complex problems, a theoretical approach may be used, a working hypothesis developed, and calculations made or trials conducted to substantiate the hypothesis. Where they exist, alternative solutions are drawn up, and suitable measures of effectiveness devised to effect a choice between the alternatives.

We have briefly discussed the methods of operations analysis, the people who may perform it, and the essentially new character of it. Because some disagreement does exist as to whether the analyst and the executive must be separate, let us define operations analysis for the remainder of this study as follows:

> Operations analysis is the application of scientific disciplines to determine the purpose, and to optimize the achievement of purpose of operations under some degree of control of an executive.

It is left to the reader the prerogative of deciding whether or not the analyst and the executive can or should be one and the same person. There still remains the important problem of showing where operations analysis can be applied.

5. Scope of Operations Analysis

Whenever a new discipline is introduced, one encounters people who arbitrarily decree that while the new discipline may work in some cases, other cases are outside its field; one also encounters people who enthuse over any new discipline and demand that everything should be subjected to it.

The history of science is filled with cases where the former have almost insisted that man remain ignorant, because it was felt that a particular problem was outside the legitimate field of science. As an example, on June 22, 1633, the Congregation of Prelates and Cardinals stated:

> The doctrine that the earth is neither the centre of the universe, nor immovable, but moves even with a daily rotation, is absurd, and both theologically and philosophically false, and at the least an error of faith.

Today, no one questions that cosmical problems are the legitimate field of science, yet it took nearly two hundred years before a decree was issued (1822) allowing books teaching the motion of the earth about the sun to be published and printed in Rome. Undoubtedly mankind has progressed a great deal since the Middle Ages and no longer has such an antipathy toward science; however, the common current attitude of indifference is little better.

Today, we still resolve a great number of problems purely on an emotional basis. As an example with which we are all familiar, let us turn briefly to the field of politics. We vote for a particular man because he belongs to a particular race, or the newspapers describe him as a great family man, or for a hundred different reasons, and we sum them all up and say, "He's a better man". But in many cases we fail to define the operation or answer the question,"Better for what purpose?" We commonly regard these problems as being outside the field of science, and make laws and regulations based upon personal feelings. Such laws often become cumbersome, so that we seek to change them. In the Twenties, a man with a bottle of liquor and a twenty dollar gold piece would be arrested for carrying the liquor; today he would be arrested for carrying the gold piece, yet the nature of neither of these

objects changed in the interim years. As members of a democracy, we believe that laws should be enacted which guarantee the greatest good to the greatest number of people, yet in many cases our voting record fails to support this belief. This may not be the fault of the voter, for often he does not possess all of the facts and must make his decision on a purely individual basis.

Can the application of the methods of operations analysis give guidance in problems of this sort? It seems to the writer that in every instance where it is possible to define the purpose of the operation, and to apply scientific methods to optimize the achievement of the purpose, it would be a valuable aid, not only in the formulating of laws, but also in providing the intelligent voter with a sound basis upon which to make his decision.

As far as those who advocate that operations analysis can accomplish everything are concerned, there are natural restrictions which limit their claims. First, there is the requirement that the executive have some degree of control over the operation. Compliance with man-made laws may effectively remove the operation from the control of the executive, in other cases the laws of nature may accomplish the same removal.

The second limiting factor in the scope of operations analysis is one's ability to decide upon the purpose of the operation. As the operation becomes increasingly complex, this problem becomes increasingly difficult.

The third limitation on the scope of operations analysis is the ability to solve a problem, once the purpose has been decided upon. Since the solution takes the form of optimizing the achievement of

purpose, it is quite evident some measurement to be used for comparison is an essential part, and the analyst must be able to produce a yardstick of values which is acceptable to all. As J. Mills (5, Page 24) wrote:

> It has been well said by one of the leading physicists of the nineteenth century that when you can measure what you are speaking about and express it in numbers you know something about it, but when you cannot, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science.

There are many problems today for which no commonly accepted yardstick of measurement exists.

This is particularly true in problems involving human beings. In many cases, the human being is the most important component in an operation, and the analyst is deeply interested in finding ways to evaluate such qualities as leadership, morale, ability, and the like. Since in repeated operations men and machines have been observed to behave in a highly predictable manner, a number of problems can be solved by making use of this repetitive feature. New developments in the fields of human engineering, psychology, and related subjects offer great hope of extending the scope of operations analysis in problems of this type.

In other fields, in the same manner that Newton invented calculus in order to make his mathematical model of the planetary system duplicate Kepler's Laws and at the same time explain the force of gravity, modern men of science are developing new disciplines such as game theory, linear programming, information theory and the like to extend the areas in which science may be applied to solve problems.

CHAPTER III

AN APPLICATION OF OPERATIONS ANALYSIS

1. The Aircraft Anti-submarine Depth Charge

Up to this point, we have discussed operations analysis in broad terms to gain some understanding of its meaning, and the scope of the problems to which it may be applied. Let us turn now to an analysis of an early application to a complex operation. The example chosen is the problem of determining the proper setting of the anti-submarine depth charge. It is a good example in that it demonstrates the difficulty of the operator in the field when faced with the problem of determining the optimum use of a relatively new weapon.

Early in World War II, the British Coastal Command used ordinary bombs against German Submarines. Since these proved ineffectual, depth charges were adapted for aircraft use. At that time, the tactics were based on a belief that the best setting was 100 feet, where the charge would be well "tamped" by the water. There were those, called "deep setters" who advocated a setting of 150 feet, as well as "shallow setters" who believed a setting of 50 feet was best. Since the settings could not be changed in flight, both sides could argue effectively as to the relative merits of their particular setting.

Let us digress for a moment and ask the question, "What is the purpose in determining the depth charge setting?" Is it to determine a setting which will insure a maximum explosive effect IF the greatest percentage of submarines is at that particular depth, or is it to determine the setting which will actually sink the most submarines? While all would agree that the true purpose of determining the setting

is to find the one that will sink the most submarines, many people failed to draw a distinction between the two purposes. These people directed their efforts toward the accomplishment of the first purpose, for they felt that if they could set the depth charges to explode with a maximum blast effect at the most probable depth of the submarine, they were automatically insuring the greatest number of submarine sinkings. But they overlooked the fact that, as the submarine sinks deeper and deeper, its "escape radius" increases much more rapidly than the "lethal radius" of the depth charge, so that the effect of "tamping" is wasted.

The problem was given to a group of British scientists. By analyzing the existing data and making use of some simple laws of probability they were able to determine the optimum depth charge setting. Their conclusion was to set the charges to explode at 25 feet, and not to drop depth charges if the submarine had been submerged for more than half a minute. Within a few months after this change in doctrine was made, the actual effectiveness of aircraft anti-submarine attacks increased by a factor of two, and the Germans announced to their navy that the British had introduced a new and much more powerful depth charge.

It is only natural, when results could be attained by the application of such seemingly simple techniques, to suppose that the solution was really simple. However, when we return to an analysis of the problem, we see that the answer was not so obvious to the participants. As far as the operators in the field were concerned, their experiences could not furnish them with the answer, for many pilots went throughout the entire war without ever sighting a submarine, and

in those cases where attacks were made, the evaluation of the effectiveness of the attack was in many cases very difficult to make. One could hardly expect the ordnance expert to furnish the solution, for while he could be counted on to furnish a very sound, scientific reason to explode a depth charge at a setting for maximum explosive effectiveness, he could hardly be expected to know aircraft attack procedures, or submarine escape tactics. The only ones who could possess all of the information necessary for the solution of a problem of this type were those in the major commands. To solve the problem required a certain knowledge of probability and statistics, as well as aircraft and submarine performance characteristics and tactics. The scientist had the mathematical background, while the operator could furnish the operational information. Together they could solve a problem which might appear very formidable to each working separately. This approach provided the solution, and resulted in a saving of time and effort entirely out of proportion to the effort involved.

CHAPTER IV

THE FORMAL OPERATIONS ANALYSIS ORGANIZATION

1. The Requirements of the Organization

The successful employment of trained scientists for assisting military commanders, such as in the instance we have discussed, led to a more or less standard type of operations analysis organization which the military has used to the present time. It is only natural that as experience was gained, that several needs and working requirements became evident if operations analysis was to be used most effectively.

First, it soon became evident that the analysis groups needed to be in a position where it was possible to obtain an overall view of the operation being studied. For only in such a position could they gain unrestricted access to all of the information so vital to analyzing a complex operation. A consideration of this need usually resulted in the analysis groups being attached near the top eschelon of command.

Secondly, it became obvious that if one scientist was helpful, two were even more so. Each particular field of science had methodologies sufficiently different to warrant their applications to various features of operational problems. This led to the formation of teams composed of scientists drawn from widely different fields of science.

Lastly, it became evident that operations analysis had utility only when applied to real problems. It created nothing new in science (although the analysis of an operation often led to research in the field of new inventions or weapons). As a result, analysis groups were most effective when assigned to organizations which had control over

the operation involved, and who had the necessary authority to implement new doctrines or tactics.

2. Operations Analysis Groups in the Navy

In April 1942 with the cooperation of the Anti-Submarine Division of the National Defense Research Committee, seven scientists were recruited by Columbia University, and assigned to the Anti-submarine Warfare Unit, Atlantic Fleet. By July 1943, the group had grown to a strength of approximately forty members. It was then incorporated into the staff of the Tenth Fleet as the Anti-Submarine Warfare Operations Research Group. Subsequently, the administrative responsibility for the group was transferred from Columbia University to the Office of Field Service, without alteration in relationship with the Navy. In October 1944, the group was transferred to the Readiness Division of the Headquarters of the Commander-in-Chief, U.S. Fleet, and renamed the Operations Research Group. At the close of the war, it consisted of seventy-three scientists, drawn from a wide variety of fields. Many of the group were attached to the staffs of fleet and type commanders, and to operating forces in war theatres.

From the nature of their assignment, it was only natural that a great portion of their effort was devoted to the anti-submarine problems This comprised over 50% of their work, and they effectively dealt with such problems as convoy screens, optimum sizes of convoys, optimum speeds of convoys, and search plans. They did important work in radar counter measures, and dealt with such submarine problems as increasing torpedo effectiveness and determination of salvo size. Much of their work is still classified. An excellent description of their methods

and the problems with which they dealt is contained in Operations Evaluation Group Report 54, Methods of Operations Research (8).

The work of the Operations Research Group is at present being carried on for the Navy by the Operations Evaluation Group, an organization comprised of fifty civilian scientists. The work of the Operations Evaluation Group is of a similar nature as that performed by the Operations Research Group. They serve as advisors to the Chief of Naval Operations, and many of their members can be found in the major commands, carrying on analytical studies of naval operations.

CHAPTER V

PRESENT NEED FOR OPERATIONS ANALYSIS IN THE NAVY

1. The Impact of Technology on Military Operations

To understand the need for operations analysis in the Navy, one must realize the tremendous impact of recent technological advances on military operations. These advances have radically changed the nature of warfare, and made the military commander's problems of decision immeasurably more difficult. Consider the case of the commander of a warship one hundred years ago, and his counterpart today. One hundred years ago, the commander could safely rely upon his experiences to guide him in his relatively simple problems of decision. Today, the situation that the commanding officer faces is much more complex, in that the tools of the operation have radically changed. With the advent of radar, high performance power plants, startling innovations in weapons systems, and the like, the commander is forced to rely more and more upon the advice of his specialists. However, like his counterpart of one hundred years ago, he must, in the final analysis, assemble all the facts and opinions and from them formulate his own decision. It is in this respect that operations analysis is the first new discipline designed to help him in the very important problems of decision. The analyst, like the commander, views the overall operation; in so doing, he must use scientific methods to establish correlation between different components of the operation to arrive at a sound basis for decision.

Operations analysis treats any type of an operation as never being fully developed. A study of the experiences of World War II reveals that whenever tactics were developed to meet an enemy threat, a change

in enemy tactics necessitated a re-evaluation of our own doctrine. Since the enemy is likewise capable of enlisting the aid of science in his operations, continuing evaluation of new advances in science, both in terms of our use and the enemy's is a military necessity. While the sense of urgency may be lessened in peacetime, in many cases the problems of decision may be more difficult. New inventions may indicate changes in operations, but certain considerations may limit their implementation. For instance, a new fuel may render existing fuels obsolete, but stocks on hand might deserve consideration. The executive must decide in terms of economy, effectiveness of the fighting forces, and availability of new equipment when to make a change. Operations analysis, with its ordered scientific approach, is a powerful aid in these problems of decision.

2. The Scientific Collection of Data

The analyst is concerned with the scientific collection of data, for data are necessary in the solution of practical problems. Since many of the problems which lend themselves to an operations analysis solution deal with repeated operations, statistically significant quantities of data are usually available. Unfortunately, in many cases where data have previously been collected, much of it is unusable. It is significant to note that during the last war, where quantities of data were collected, many months were needlessly spent by Operations Research Groups in sifting masses of irrelevant data to obtain pertinent operational facts. The collection of data is both time consuming and costly and thus is a problem which deserves consideration. The analyst has had special training as a scientist in making observations and determining what data are

significant to a problem, and it seems to the writer that fuller employment of the services of the analyst in the scientific collection of data is desirable.

The methods of operations analysis may be readily applied to the preparation of data request forms, in that the purpose should first be subjected to careful analysis and then the form prepared to optimize the achievement of that purpose. Once the data have been collected, IBM machines may be used to process them. In this form data may be easily stored for subsequent use if the need arises.

3. Liaison Between the Scientist and the Executive

As the world becomes increasingly technical, the gulf between the executive and the scientist widens. The practical inventor has almost vanished from the scientific scene today, giving way to the formally trained teams of researchers, exploring new concepts unfamiliar to most people, and employing their own scientific language. While Ruskin may have over simplified when he observed, "A great deal of the supposed scientific writing of the day is simply bad English, and vanishes the moment you translate it", even this matter of translation may pose a very effective barrier to most executives. Operations analysis provides a bridge between the executive and the scientist.

When one considers the need for solving problems imposed by new technological advances, the collection of data, and liaison between the technical world of science and the executive, the continuing need for operations analysis in the Navy is evident. Certainly no one expects future operations to become less complex, and if anything this need must grow. Heretofore, all formal operations analysis for the Navy has been performed by groups of civilian scientists. Recently, the Navy has

instituted a program of training naval officers in operations analysis. The next two chapters will discuss some of the advantages and problems of using either civilian or officer analysts.

CHAPTER VI

THE CIVILIAN ANALYST

1. Preservation of the Civilian Atmosphere

Most civilian analysts believe that the preservation of their civilian status is an essential requirement in their performance of operations analysis for the Navy. The working routine of the scientist runs counter to that of the military man in many respects. The military man lives in a world of real problems, and is accustomed to giving decisive orders. An operation can't be stopped until the military commander makes up his mind. On the other hand, the civilian scientist believes he should be divorced from the responsibility of issuing orders about an operation, and instead should be able to study the operation as it proceeds. It is not implied that the military man gives orders without serious reflection on the problem, or that the scientist cannot give an order, but rather that the military man must decide upon the evident facts at hand, utilizing experience and guidance from other sources, while the scientist, in his employment of scientific methods, accepts only those things which can be proven. Urgency dictates the former, while the latter is demanded for sound analysis.

The civilian analyst feels that deference to higher authority may prevent the analyst from arriving at the true solution of a problem, and believes that this danger is more apt to occur if he is a member of a strongly disciplined military organization. There is, of course, a danger that any analyst will include only those facts which are consistent with a senior's wishes. Such a practice can hardly be called operations analysis, and may be disastrous in that the executive may

be misled into placing more faith in the report than it deserves. The civilian analyst believes his status enables him to approach all ranks in the military organization with greater equality.

We have briefly discussed the importance of the operations analysis team. In this respect, the use of civilian groups has distinct advantages because of their ability to find, train, and keep the right personnel. Provided that the scientist is available, the only problem of the group is to enlist his services. They can afford to be selective, and can rapidly advance the most capable members. Closely associated with this ability to staff a team with competent members, is the problem of training. The finished analysis represents the composite views of the members, and the healthy freedom of discussion and simultaneous preparation of the analysis, lend themselves easily to an "on the job" training program. The civilian group can offer greater permanence to its members, and hence does not have the problem of rebuilding the organization periodically. The members of the civilian groups are scientists working in their chosen fields of study. When a member desires more formal training, such opportunity can readily be made available to him. Because they have the opportunity to retain their professional competence they can remain in close touch with all of the advances of science.

2. Problems Arising in the Employment of Civilian Analysts.

It is well for the military man to have an understanding of some of the problems of the civilian analyst, for he is often in a position to help him. One of the most important handicaps of the civilian analyst is his lack of operational experience. For the analyst to truly understand the problem, he must have some feeling for the operational environment, particularily as it effects the human component. The simple,

mathematical solution of a search problem, employing a definite range law of detection, may become a very difficult operation to an exhausted search crew, buffetted about by the elements. It isn't that the analyst is not aware of these problems (in many cases they have done a great deal of work making the military more aware of them); the point is, that just as there is need to acquaint the military man with the ways of the scientist, there exists a need to acquaint the analyst with the operation, and in both cases a considerable time for indoctrination is required.

The problem of determining the civilian analyst's position in the military organization is often times a difficult one. When the military formally contracts for operational analysis, about the only serious problems that arise are in regard to security restrictions and in providing operational data and trials. However, when the analyst is called upon to work in the theatre of operations, difficulties arise in defining his status in the command organization. This is a real and vexing problem, as Kimball and Morse (7, Page 140) in writing of the experiences of the Operations Research Group have noted:

> In an outlying theatre of operations, however, it is usually necessary for the worker to be in uniform. Sometimes the worker has been given a temporary rank, sufficient for him to perform his functions without undue embarassment. This temporary rank has some disadvantages, however, for it immobilizes him in the military hierarchy and makes it difficult for him to approach lower echelons on terms of equality. Sometimes it has been possible to avoid the question of temporary rank and give the worker some special insignia. This also has difficulties, for proper accommodations and entrance into necessary headquarters are often only available to officers, and the special insignia may not be recognized as being the equivalent of an officer.

It can be seen that many of the problems which arise when civilian analysts are employed, are those which can best be resolved on an

individual basis. Civilian groups have made vital contributions to the success of military operations in the past, and it seems only logical to assume that the demands for their services should continue in the future.

CHAPTER VII

THE OFFICER ANALYST

1. The Training of the Officer Analyst

As already noted, the Navy has instituted a program of training officer analysts at the U.S. Naval Postgraduate School, The purpose of the curriculum is to educate officers in the basic sciences and to provide a thorough grounding in the theory and methods of operational analysis, in order that they may direct the analytical approach to complex naval problems.

The question of whether or not one can learn operations analysis as a result of formal training is of fundamental importance. In this country, an increasing number of prominent colleges and universities are giving formal instruction in operations analysis. They include: The Case Institute of Technology, Dartmouth College, John Hopkins University, and The Massachusetts Institute of Technology. The Illinois Institute of Technology has announced the addition of a graduate course, called "Introduction to Operations Research", and the Massachusetts Institute of Technology has established an Interdepartmental Committee on Operations Research to inquire into and advise on training students in the field. The most extensive instruction offered anywhere in operations analysis, is that given at the U.S. Naval Postgraduate School. Many of its faculty members have had experience with operations analysis groups. The Navy, along with the above civilian institutions, believes that operations analysis has progressed to the point which permits formal instruction in its methodology, but recognizes that a basic understanding of the sciences is necessary for its applications.

At the present time, the mathematics portion in the operations analysis curriculum at the U.S. Naval Postgraduate School consists of 54 hours, which includes vector analysis, differential equations, probability and statistics, matrix theory, theory of games, statistical decision functions, and high speed computing machines. The physics portion consists of 47 hours, and includes courses in optics, analytical mechanics, electricity and magnetism, acoustics, kinetic theory and statistical mechanics, atomic physics, and nuclear physics. At present 34 hours are devoted to formal operations analysis studies, including an introductory course, search theory, effectiveness of weapons, optimal weapons systems, logistic analysis, and theory of information. Survey courses are given in chemistry, radar, operational aspects of meteorology, and aircraft performance evaluation. Summer field trips are planned so that the students are given an opportunity to visit and work with civilian and military organizations having operations analysis groups.

2. Problems Arising in the Employment of Officer Analysts.

Just as there are problems which arise when civilian groups are employed to do operations analysis for the military, there are problems that arise when naval officers are employed. Some of these are of such a serious nature as to raise the question of whether or not these officers can ever be considered true operations analysts. In this connection, the writer is not considering the case where the typical officer applies the methods of operations analysis to arrive at solutions of his problems, for it is felt that this is both feasible and desirable, but rather to the general subject which deals with the professional competence of the officer specifically designated as an operations analyst.

The civilian analyst is basically a scientist, engaged in the pursuit of his life's work, Surrounded by other competent scientists, he has the opportunity to study the latest scientific advances and to readily avail himself of further formal education in scientific fields. On the other hand, the officer analyst is above all a naval officer. As is true for any officer, he must insure that his experiences qualify him for promotion when due; thus his rotation in duties will bring about assignments where he is not acting in the formal capacity as an operations analyst. While this is a problem which faces all officers with a specialty, unless the analyst actively works on operations analysis problems, the benefits of his formal education may be largely lost. As a naval officer he is expected to actively participate in the operation (as contrasted with the civilian analyst who figuratively sits on the side lines and studies the operation) and shoulder his share of collateral duties. Were he not to do this, it would soon reflect on his competence as a naval officer.

There are questions which arise when we consider the status of the officer analyst in the command organization. We have briefly discussed the importance of having an overall view of the operation. It is the military philosophy that knowledge of the operation, responsibility, and authority go hand in hand. In turn, responsibility and authority go with rank. We have already noticed that civilian analysts have felt that the desired status in the organization is one which permits knowledge of all aspects of the operation, but which is accompanied by little power and responsibility. The writer is not sure which is the more incongruous, the officer analyst with high rank and little authority

and responsibility, or the officer analyst with low rank and broad knowledge of the operation.

In military organizations the chain of command is scrupulously adhered to. This is necessary, otherwise conflicting orders and confusion arise. The officer analyst will, of course, take his proper position in this chain of command. This may effectively limit the analyst's knowledge of the operation; at the very least it will often occasion the transmission of technical information via non-technical channels with obviously undesirable effects.

We have briefly discussed the importance of the operations analysis team. So widespread is the belief in the team effort, that it is often used as the defining feature of operations analysis. L.A. Brothers (1, Page 16) writes:

> Operations analysis is team research. A team of analysts is assigned to a problem, the analyst being selected so as to bring to bear on the problem the scientific skills judged most applicable to its solution.

P.M. Morse (6, Page 603)notes:

> .....a number of branches of science are called upon for help. For example, physics is required for a basic understanding of the operational possibilities of the machines involved, and biophysics and psychophysics are required in order to understand the capabilities of the human components. Mathematics is basic to all of the work.....During the war it was found that a mathematician, a physicist, and a biologist together make up a research team of considerable effectiveness.

The benefits of team research is perhaps best expressed by Newton's modest statement, "If I have seen further than most, it is because I stood on the shoulders of giants". One of the first questions of the officer analyst might well be in regard to his team. It would certainly be presumptious for him to believe that he alone could perform an analysis as efficiently as the previously required team of scientists.

Another point which should be considered in the use of officer analysts is the problem of centralization to avoid duplication. In an organization such as the Operations Evaluation Group, all analysts, including field workers, know what problems the organization is working on. At present there is no established procedure permitting the officer analyst in one command to know what another command has done except where the results are made available in print. It is in the formulating and solving stage of the problem that the free exchange of information is most helpful. Without some form of direction, considerable duplication of effort will result.

The writer has no way of knowing to what degree the above problems will determine the eventual effectiveness of the officer as an analyst; as in the case of the civilian analyst many of them can undoubtedly be resolved on a personal basis. They do, however, seem to merit consideration lest operations analysis be thought of as just another form of staff study. It is, of course, too early to determine the true value of the officer analyst, for it will depend largely upon the individual competence of the officers assigned to this duty, as well as recognition of the need for their services.

3. Advantages in Using Officer Analysts.

As in the case of the civilian analysts, there are several special reasons why the naval officer should make a good operations analyst. His operational background should prove invaluable to him in the formulation and solving of the problem. Because he is a member of the operational organization, his problem in overcoming security and censorship regulations should be less difficult than his civilian counterpart. Since he

is at the scene of operations, his training should enable him to recognize problems where operations analysis can be applied without waiting for others to formally request a study.

While we have talked largely about considerations involved in the actual solution of problems, we have noted that this is only one phase of operations analysis. With regard to the scientific collection of data, liaison between the executive and the scientist, and evaluation of operational analysis studies made by other agencies for the Navy, the training the naval officer has been given should prove of great worth to the Navy.

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

1. Future Uses of Operations Analysis in the Navy.

In this study we have discussed in general terms the meaning of operations analysis and its scope. Previously in the Navy, operations analysis has been applied largely to problems arising in combat operations such as in the example of the aircraft depth charge problem. This is in keeping with the idea expressed in OEG Report 54 (8, Page 138) which states:

> It must be apparent that an operations research group must be attached to the operational commands in a military organization. The logistic and technical commands have their problems requiring scientific personnel for their solution, but this sort of work is not what is meant by operations research.

Since that time, however, the methods of operations analysis have been applied in many widely different fields with success, and it seems unwise to restrict unnecessarily the types of problems dealt with by operations analysis groups in the Navy. Such applications have ranged all the way from studies of "Utilization of Negro Manpower in the Army"(3) to "Application of the Simplex Method to a Transportation Problem"(4). In particular, important work is being done on problems related to inventory control; a matter of obvious interest in the field of Logistics. In the same manner, studies such as "The Failure of Complex Equipment"(10) may prove to be of original interest to the technical commands.

In operations analysis, as in all fields of scientific research, discoveries in one field are often of great importance in a seemingly different one. As an example, in the field of Economics, Leontieff's Input-Output technique of studying the national economy is a new idea to develop quantitative methods for dealing with the enormous amounts of

empirical data involved in every real economic situation. Yet its principle appears to be capable of application to such a seemingly different problem as the task of programming individuals into a training organization. In the final analysis, it would be difficult to find any department of the Navy which would not be able to benefit through the application of the methods of operations analysis. At the present time, there are few analysts in the Navy, and many officers are unfamiliar with this new discipline. As this situation is corrected, more and more problems can be subjected to its discipline.

2. Civilian or Officer Analyst.

When one reviews the respective qualifications and working conditions of the officer analyst and the civilian analyst, the question as to which to use loses a great deal of its significance. It is apparent at once that there are many cases wherein each can assist the other. The civilian analyst prefers his status because he can work on a problem, detached from the responsibilities of operational decisions. In so doing, he is dependent upon the executive to furnish him problems and operational data. By drawing upon the knowledge possessed by other scientists of the team, the civilian analyst is in a position to work on very complicated problems. His status enables him to move freely in scientific circles. On the other hand, the officer analyst may find that his close contact with the operation is beneficial for an understanding of the problem, but his participation in the operation may seriously reduce the time he has available for scientific research. In the absence of assistance from a team of fellow analysts, the types of problems he can solve will be necessarily restricted. He will be able to move freely in the military organization since he is a member of it, but the problem of following the latest scientific advances will be a difficult one.

The writer believes that both the civilian analyst and the officer analyst have definite roles to perform in the Navy, and that the question which should be of interest is not which one to use, but rather, how can each be used most effectively?

This question may be answered in part by providing liaison between the civilian group and the officer analyst. The officer analyst, at the scene of the operation, may serve the civilian group in the same manner as their presently employed field workers, while the civilian group is in a position to assist the officer analyst in the solution of many problems beyond his ability. At the present time this liaison is conspicuous by its absence, yet the mutual benefits which could accrue indicate that consideration should be given to provide this liaison.

At the present time, operations analysis is an unfamiliar discipline to most of its potential users. In line with the problem of employing the analyst most efficiently, studies should be made on how best to acquaint all naval officers with uses of operations analysis in the Navy. Undoubtedly, the usual general information articles would be helpful. Formal introductory courses could be given at institutions such as the Naval Academy, The General Line School, and the War College. At present, instruction in operations analysis at the Naval Postgraduate School is limited to line officers. In view of the many possible applications of operations analysis to problems other than those arising in combat operations, consideration should be given to lifting this restriction.

3. Summary

One sees in operations analysis another manifestation of man's never ending struggle to gain control over situations in which he finds himself. Science, in its search for truth, adds to man's knowledge and increases

this control, while operations analysis provides him with answers of how best to exercise this control. As a new discipline, operations analysis suffers the usual growing pains resulting from a lack of accepted definition of scope and purpose. This is to be expected, since the evolution of any new scientific discipline is at best a slow process. Those who find its methods too slow, or its applications too limited should not be discouraged, for we can use it imperfectly and in part while it is developing.

Operations analysis, by using scientific methods to decide upon a purpose and then optimize the achievement of this purpose, provides a sound basis upon which to make decisions. If we rigorously follow the methods of operations analysis, we can feel confident that the decision we reach will be the most reliable that can be attained at present.

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